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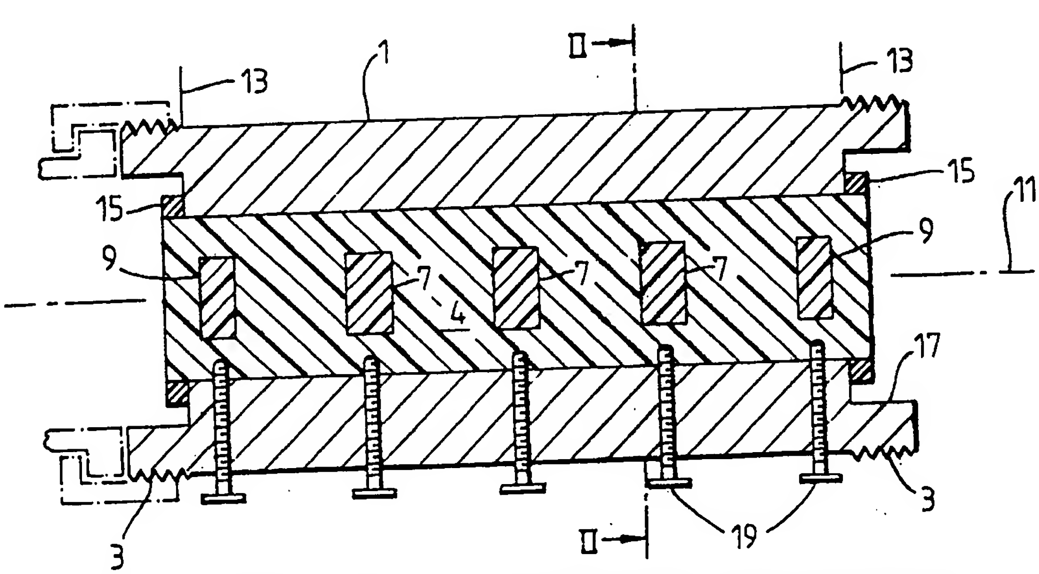
(54) **Waveguide filter**

(57) A waveguide filter for use in a DBS system operating in dual mode with orthogonal polarization planes. The filter consists of a circular waveguide 1 containing a series of dielectric resonators 7,9 supported, spaced apart, in a body 4 of low dielectric constant material. The resulting filter is provided with circular waveguide couplings for direct connection to waveguide section. Efficient coupling of the filter to waveguide is achieved by selection of the various parameters: size, shape, spacing of the dielectric resonators, dielectric constant of the dielectric resonators and the supporting material, and guide dimensions. A dual mode bandpass filter operating at about 12 GHz can thus be achieved at very low cost.

Fig.1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

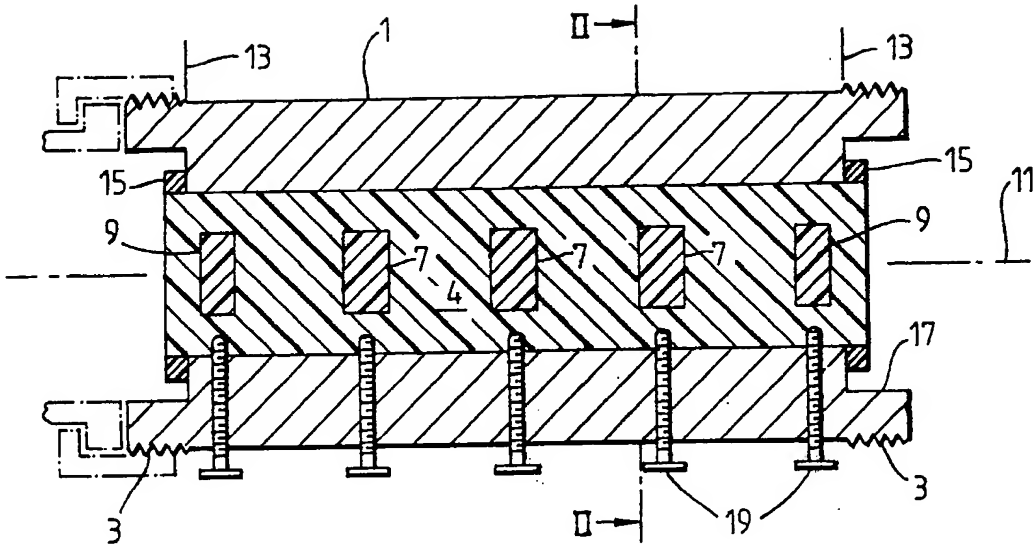
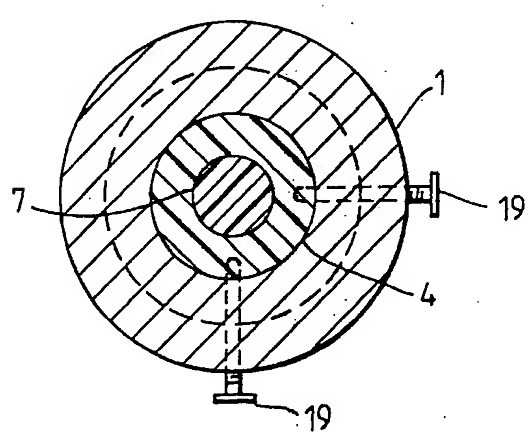


Fig.2.



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Waveguide Filter

This invention relates to a waveguide filter which may, for example, be used in a Direct Broadcast Satellite (DBS) receiving system.

Such systems commonly comprise a dish or other antenna, a microwave circuit known as a low-noise-block (LNB) mounted at the focus of the dish, and a receiver fed by the LNB. The LNB has a basic function of frequency conversion, reducing the satellite carrier frequency, typically at Ku band, to a more manageable value.

Low Noise Block down-converters sometimes need to be protected from external out-of-band interference originating from terrestrial or space sources by providing a filter at the input. Such a filter must be of low cost and work with orthogonal sets of linear or circular polarization between which the various channels are distributed. The filter must also interface with the circular (or square) waveguide from the feed horn, and with the LNB input. Typically such a filter requires a bandpass characteristic at Ku band: a typical example would pass 10.95 to 11.7 GHz with negligible loss whilst rejecting signals several hundred MHz out-of-band by 40dB.

Normal methods of providing such filter protection for two orthogonal polarizations would employ an Ortho-Mode Transducer (OMT - to separate the two polarizations) with separate conventional waveguide bandpass filters for each resulting polarization. The two signal paths can then be recombined by switches, OMT, or other means to feed a single LNB: alternatively, separate LNBs can follow each filter. Such solutions are complex and expensive.

Another function of such filters is to provide additional image frequency rejection and to suppress leakage of internal LNB signals such as that due to the local oscillator used for the down conversion process.

One object of the invention is to provide a single filter which will act on both polarizations (whether they be linear or circular).

Dual-mode band pass filters have been proposed previously, in a paper entitled "Canonical and Longitudinal Dual-Mode Dielectric Resonator Filters Without Iris" by Zaki, Chen and Atia, IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-35, No.12, December 1987. This paper describes a cylindrical filter comprising a number of dielectric resonator elements of short cylindrical form spaced apart along the axis of the filter to form a canonical arrangement of coupled cavities. It is explained in the paper that the equivalent circuit for this filter consists of a series of pairs of filter circuits coupled in cascade along each half of the series and cross coupled between each pair. The polarization plane is 'flipped' in each cross coupling, from one orthogonal plane to the other, so that the filter operates on both planes. The cross coupling is effected for each cavity, by screws inserted into the matrix material of the filter (a cylindrical dielectric body in which the dielectric resonators are suspended).

The coupling screws are essential to this form of filter and have one or other of two arrangements, providing equal or different cross coupling between successive pairs of filter elements according to the particular realization, canonical or longitudinal.

Inherent in this prior filter are input and output couplings provided by coaxial connectors or dipole and coaxial connector. These determine the polarization plane orientation and also the very critical orientation of the successive coupling screws which are set at 45° to the polarization planes.

A further object of the present invention is thus to simplify the filter construction.

According to the present invention, a dual-mode microwave filter for use with orthogonally polarized signals comprises a waveguide containing a body of relatively low dielectric constant, a plurality of dielectric resonant elements of relatively high dielectric constant spaced apart along the axis of the waveguide within the said body, the ends of the waveguide being provided with axial waveguide couplings to provide respective input and output, and the dimensions and spacing of the dielectric resonant elements being such as to provide a bandpass characteristic in respect of both orthogonal modes.

The waveguide may terminate in coupling planes at which there is a step increase in the waveguide dimension, the body extending substantially to the coupling planes.

The dielectric resonant elements may be of cylindrical form, having axes aligned with the axis of the waveguide, and the axial lengths of the endmost elements being equal and less than those of any other of the dielectric resonant elements.

There may be a plurality of dielectric resonant elements between the endmost elements, these inner elements being of equal axial length.

In such a filter the inner element spacing may be constant, the inner/endmost spacing between each endmost element and its nearest inner element being less than the said constant spacing, and the spacing between each endmost element and the adjacent waveguide coupling plane being less than the inner/endmost spacing.

A waveguide filter for use in a DBS system will now be described, by way of example, with reference to the accompanying drawing in which:

Figure 1 is a diagrammatic section on the filter axis;

and Figure 2 is a transverse section on line II-II of Figure 1.

The filter consists of a section of circular evanescent waveguide 1 terminated by circular waveguide couplings 3. The wavefuide incorporates a body 4 of expanded polystyrene, having a low dielectric constant of 1.02 or less, which body encapsulates a number, in this case 5, of dielectric resonators 7 and 9. These resonator elements are of cylindrical form and are spaced along the axis 11 of the filter with their axes aligned with this axis. They are all of diameter 5.95 millimetres ± 0.01 millimetres but, while the inner ones 7 are of axial length 2.2 millimetres the endmost two, referenced 9, are of axial length 1.9 millimetres. The axial lengths have a tolerance of -0.01 +0.00 millimetres. The resonator elements are of known form consisting of a titanate ceramic, zirconium or barium titanate for example, or that known as ZTS. The dielectric constant of this latter material is relatively high - 37.

At each end of the evanescent guide is the coupling plane 13 of the filter, at which there is a step change, an increase, in diameter, from the evanescent guide at 12.2 millimetres diameter to the normal guide diameter of 18 millimetres. The metal guide 1 provides, in the region of this plane 13 a screw coupling 3 by means of which a standard guide section (or other component, eg LNB or feed horn) can be coupled to the filter, being drawn against the end face 6 of the guide 1 to provide a continuous internal surface 17.

The spacings of the resonator elements within the body 4 are: 1.2 millimetres between coupling plane 13 and endmost resonator element 9; 8.6 millimetres between endmost resonator 9 and next inner resonator 7; and a constant 9.9 millimetres between successive ones of the inner resonators 7. The filter is thus symmetrical about a central transverse plane.

The resulting length between the above coupling planes 13 is thus 49.8 millimetres.

The dielectric (polystyrene) body 4 and its included dielectric resonators may be formed by moulding the body 4 in two halves (split by a plane containing the axis 11), inserting the cylindrical resonators 9 and 7, and sliding the assembled body and resonators into the guide 1. A polystyrene ring 15 fixed by adhesive at one end limits the movement of the body 4 into the guide 1 and a similar ring 15 is attached after insertion. These rings locate the body 4 and resonators 7 and 9 axially with respect to the coupling planes 13.

Tuning screws 19 may be fitted into the body 1 of the filter, in the planes of the dielectric resonator elements. It should be noted that, where fitted, these tuning screws are in the polarization planes of the orthogonal mode signals, ie, as shown in the drawings, in the vertical and horizontal planes. Suitable tuning screws are approximately 2 millimetres diameter and have a thread form of about 3 turns/millimetre. Such tuning screws provide a refined control of the resonant frequency of the dielectric resonators and are in no way fundamental to the operation. They can in fact be omitted with only slight deterioration and should be contrasted with those coupling screws in the above referred to paper, ie those at 45° to the orthogonal planes, which provide essential coupling between the side-by-side filter units such as to 'flip' the polarization plane of the signal. In the present invention there is no 'flipping' or rotation of polarization plane throughout the filter length - the two modes are processed in parallel by the dual mode dielectric resonator elements from the input at one waveguide coupler to the output at the other.

The number of dielectric resonators determines the precise form of the characteristic but clearly, where space is at a premium the number is limited. 5 elements, as shown, does provide a satisfactory bandpass characteristic for most purposes.

While circular section dielectric resonators and waveguide have been described, other regular sections may be employed - square, hexagonal etc.

Coupling between successive stages in the filter is achieved without the use of irises by careful selection of the various parameters described above, including the spacing between the dielectric resonators. Additionally, efficient coupling between an external circular waveguide and the evanescent guide 1 has been found to be feasible by appropriate choice of the above parameters, including particularly the position of the endmost resonator elements 9 in relation to the coupling plane 13. The coupling between the endmost puck 9 and the external waveguide, which may be referred to as the external Q of the filter, is strongly dependent upon the position of the endmost puck 9 in relation to the coupling plane 13. The realization of the feasibility of this feature is fundamental to the invention. The relative dimensions of the waveguide sections; the choice of dielectric constants for the resonators 7, 9 and the body 1; and the shape, size, resonant mode and frequency of the individual resonators, all contribute to the efficiency of the filter/waveguide coupling.

In use in a DBS system, one end of the described filter is coupled to a dish feed to receive the focused signal and the other end is coupled to an LNB. The orthogonal mode signals, thus 'cleaned up' are converted by the LNB to a lower frequency, of the order of 1 GHz, for further processing and display.

CLAIMS

1. A dual-mode microwave filter for use with orthogonally polarized signals and comprising a waveguide containing a body of relatively low dielectric constant, a plurality of dielectric resonant elements of relatively high dielectric constant spaced apart along the axis of the waveguide within said body, the ends of the waveguide being provided with axial waveguide couplings to provide respective input and output, and the dimensions and spacing of the dielectric resonant elements being such as to provide a bandpass characteristic in respect of both orthogonal modes.

2. A filter according to Claim 1, wherein said waveguide terminates in coupling planes at which there is a step increase in the waveguide dimension, said body extending substantially to said coupling planes.

3. A filter according to Claim 1 or Claim 2, wherein the dielectric resonant elements are of cylindrical form, having axes aligned with the axis of the waveguide, and the axial lengths of the endmost elements are equal and less than those of any other of said dielectric resonant elements.

4. A filter according to Claim 3, wherein there are a plurality of dielectric resonant elements between said endmost elements, these inner elements being of equal axial length.

5. A filter according to Claim 4 as appendent to Claim 2, wherein the inner element spacing is constant, the inner/endmost spacing between each endmost element and its nearest inner element is less than said constant spacing, and the spacing between each endmost element and the adjacent coupling plane is less than said inner/endmost spacing.

6. A filter according to Claim 5, having a passband in the Ku band, wherein said inner elements have a diameter of 5.95 millimetres, and an axial length of 2.2 millimetres, and said endmost elements have a diameter of 5.95 millimetres and an axial length of 1.9 millimetres.

7. A filter according to Claim 6 as appendent to Claim 2, wherein said inner element spacing is 9.9 millimetres, said inner/endmost spacing is 8.6 millimetres, and the endmost-element/coupling plane spacing is 1.2 millimetres, said step increase being a diameter increase from 12.2 millimetres to 18 millimetres.

8. A dual-mode microwave filter substantially hereinbefore described with reference to the accompanying drawings.

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